National Aeronautics and Space Administration

Early Edition

Age of the Universe: *13.7 Billion Years*

Cosmic Times

2006

Size of the Universe: *94 Billion Light Years*

Faster Walk on the Dark Side

The universe is expanding faster and faster. New evidence is showing astronomers that dark energy is causing this increase in speed. Dark energy, which is a mysterious anti-gravity energy, makes up almost 75% of the universe. Not much is known about dark energy, except that it works against gravity, and makes galaxies move apart faster than astronomers expected.

The new evidence that astronomers found is the effect dark energy has on light from the earliest universe. This old light started its trip across the universe only 380,000 years after the Big Bang. Since then, in 13 billion years, the energy from that light has cooled down to microwave energy. Today, we observe that microwave energy as cosmic microwave background radiation, or CMB. And since 1967, scientists noticed something called the Integrated Sachs-Wolfe effect (ISW) acting on the CMB.

The ISW effect was named after the two astronomers who first described it, Rainer Kurt Sachs and Arthur Michael Wolfe. Recently, scientists from around the world confirmed its effect on the cosmic microwave background. Three teams helped with the work, including Stephen Boughn of Haverford College, Robert Crittenden of the University of Portsmouth, and the WMAP team led by NASA's Charles Bennett. Along with the three teams, Bennett's team was helped by astronomers from the Sloan Digital Sky Survey Team, who also worked with Pablo Fosalba and his co-workers at the Institit d'Astrophysique de Paris.

All of the scientists put together their valuable information on the large-scale structures of the universe. They also gathered new data on light from the early universe, by using the CMB we see today, in order to reach their conclusions. All of their data included observations from visible light and from telescopes that read x-rays, radio waves, and microwaves.

Here is how ISW works. First of all, gravity is a property of matter. In space-time, matter exists in "gravity wells," or pockets of gravity. More matter makes a deeper well. Normally, when light travels

"Dark side" continued on page 2

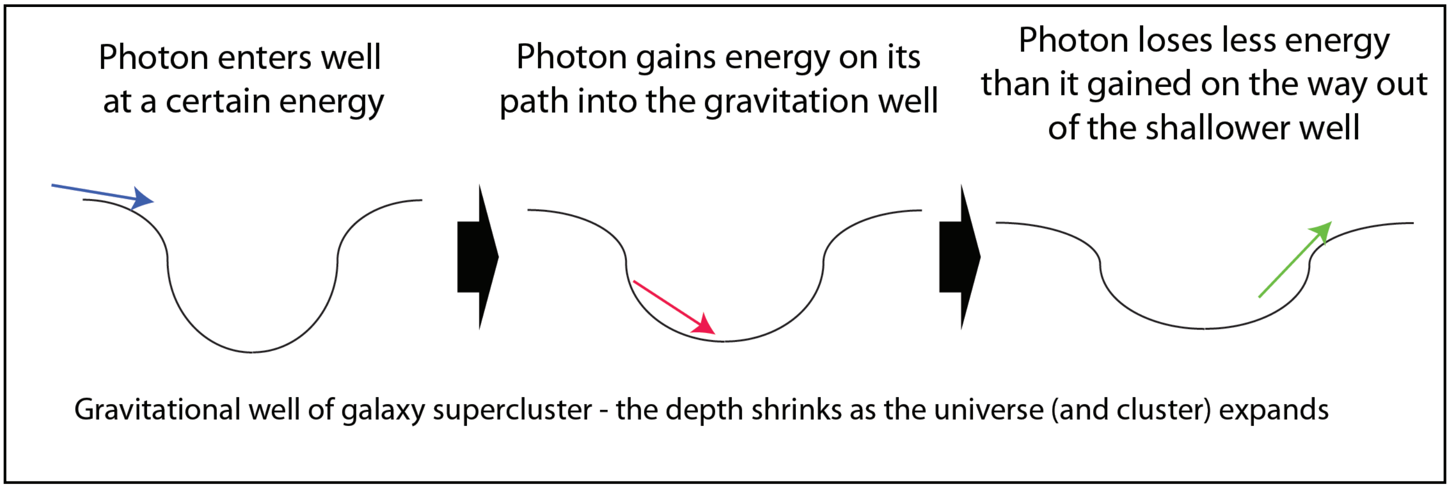

Illustration of the Integrated Sachs-Wolfe effect.

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into a gravity well and then travels back out the other side, the well does not affect the energy of the light. But if dark energy stretches out these deep wells of gravity, making them large and shallow, then the energy of the light passing through the well will change. This also affects the energy of the CMB light crossing the well. The scientific teams who studied ISW found that there were slight changes in CMB's energy, providing evidence of dark energy.

This was good news for two teams of astronomers who first discovered signs of dark energy in 1998. They found that galaxies were moving faster than they should be. To figure this out, they measured the speed that very far off Type Ia supernovae inside other galaxies moved away from our galaxy. The Supernova Cosmology Project Team at Lawrence Berkeley National Lab and the International High-z Supernova Search Team were trying to measure how quickly the expansion of the universe was slowing down. Instead, the measurements from the supernovae showed that the distance between Earth and the far-off galaxies was increasing faster and faster. It was like an invisible force of "dark" energy was working against gravity and pulling galaxies apart. Even more surprising, they found that this increase in speed started just five billion years ago.

The researchers named this mysterious force dark energy. Dark energy is different than dark matter, which is another mysterious problem in the study of the universe.

What is dark energy? No one knows yet. There are at least six hypotheses and none of them seem to be close to finding an answer.♦

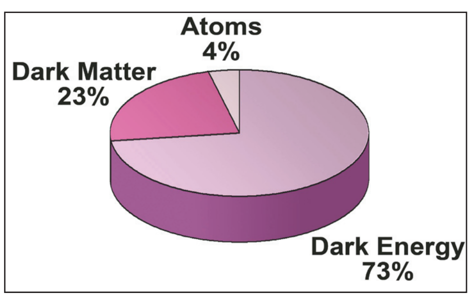
Biggest Mystery
What is Dark Energy?

The farther we look into the known universe, the more confusing it is for scientists. Astronomers are now struggling with the problem of dark energy. So little is known about dark energy, even though it is the largest, most important stuff of the universe. At this point, it is a big mystery.

There are several hypotheses right now that are trying to explain dark energy. Testing these ideas has been very hard to do. To do this, astronomers need new scientific instruments to search deeper into the universe.

Scientists don't know what dark energy is, but they know what it does. Dark energy creates more space by pushing galaxies farther apart. This makes the whole universe grow at a faster rate. In the late 1990s, studies of far-off supernovae showed that the space in the universe was growing larger faster than they first thought.

Even before astronomers discovered dark energy, there were hints that it existed. Albert Einstein wrote about an "anti-gravity" effect called the Cosmological Constant when he came up with his Theory of General Relativity. This "anti-gravity" allowed the universe to be unchanging, as Einstein had assumed the universe to be. When Edwin Hubble discovered that the universe was expanding, Einstein and other scientists thought the Cosmological Constant was some kind of annoying "fudge factor," that had no connection to the real universe.



Astronomers have found that 4% of the universe is made of "typical" atoms, 23% of the universe is made of dark matter (which does not give off or absorb light), and 73% is made of dark energy (which is making the universe's expansion speed up). (Credit: NASA/ WMAP Science Teams)

After Einstein, later researchers described his Cosmological Constant as a kind of background energy. They thought that the background energy might affect the universe. Unfortunately, the figure Einstein came up with predicts that the energy should be much stronger than dark energy seems to be.

A modern idea is that dark energy is something called "quintessence." This is the same word that the Greeks used for a mysterious fifth element (the Greeks thought that there were four basic elements—earth, wind, fire, and water). This new idea of quintessence is different than Einstein's Cosmological Constant. Quintessence's hypothesis is that it is an energy field that pushes particles apart. This can lessen over space and time. The explanation makes sense because scientists have observed that dark energy has only been acting on the universe for about the past 5 billion years, meaning its effect is not continuous.

Scientists need to learn much more about dark energy's impact on the universe in order to test their hypotheses. The only way to do that is to gather more data from the universe. ♦

Sorting Out Dark Stuff

The universe has some good news and some bad news. The bad news is that everything we can see, everything that is visible—the sun, the Earth, humans—is only 4% of the known universe. But the good news is that humans are beginning to figure out what makes up the other 96% of the universe.

Dark matter makes up more of the known universe than atoms, but that's not all. Atoms make up only 4% of the known universe, and dark matter makes up another 23%. That means that all matter, both visible matter like atoms and undetectable matter like dark matter, is still only a small part of the known universe, with the rest of the universe made of dark energy. Dark energy is 73% of the universe. Both dark matter and dark energy are mysterious. They are very different from one another, but have both been called "dark" because we can't directly sense them (they aren't found through our senses—sight, sound, taste, smell, etc.).

Dark matter is the universe's "missing mass." It does not interact with normal matter, like atoms, except to pull on it with gravity, which is how we know it is there. Dark matter was first discussed by astronomers in the 1930s. When they found that the amount of visible matter in galaxies was not enough to explain the mathematical results of gravity's effects of one galaxy on another, they knew something else had to be there. Today, scientists think dark matter is a kind of cold particle that interacts weakly with both atoms and with light.

But dark energy is an even stranger idea. Scientists know it exists because it flings everything else apart. Right now, this unexplained energy is making more space out of nothing, and pushing everything apart faster and faster. That's good news if you like privacy!♦

First Light Wins Nobel

The 2006 Nobel Prize for Physics was awarded to John Mather and George Smoot for their 1992 discoveries about the cosmic microwave background. The CMB is the remaining light and energy from the beginning of the universe.

The pair were awarded the Nobel for how their measurements of the CMB have contributed to cosmology, or the study of the universe. A quote from the Nobel Prize committee, who awards the Nobel Prize, said, "these measurements marked the start of cosmology as a precise science."

A team of researchers led by Mather and Smoot used data from the space-based COBE (Cosmic Background Explorer) to figure out how the universe has cooled. When they measured the energy of light from the CMB, they found that it perfectly matched predictions from the Big Bang Theory. They also found very slight variations, or differences, in the microwave light. If those differences were not found, it would have been hard to explain how the universe got its present shape and composition. Later experiments fine-tuned the COBE data, but the basic discovery of the variations in the CMB by Mather and Smoot remains.♦

John Mather

Seeds of **Modern** Universe

Cosmic researchers now have the clearest view ever of the universe's early structure. They can see clusters of galaxies, and clusters of clusters of galaxies. The better view comes from super-sensitive temperature data of the cosmic microwave background (CMB). The WMAP, or Wilkinson Microwave Anisotrophy Probe collected this data. If you remember, the CMB is the left-over energy from the Big Bang.

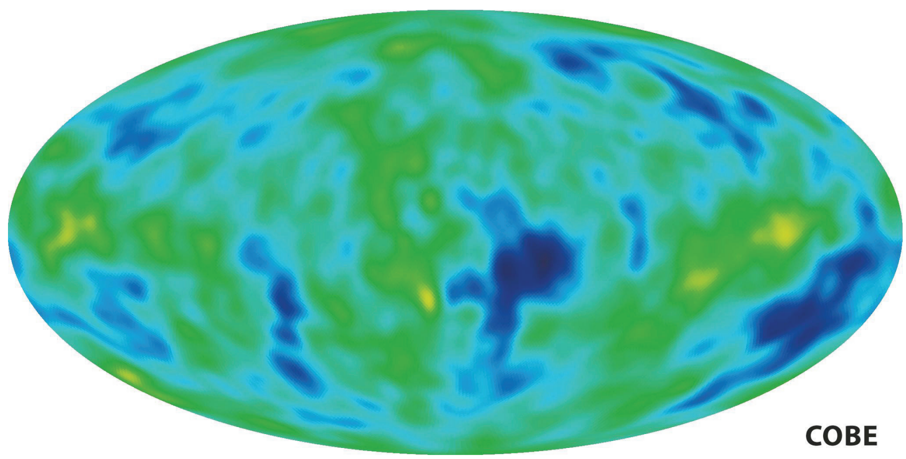
WMAP is a much clearer map than the first map of the CMB that was made from COBE, or NASA's Cosmic Background Explorer satellite, in 1993.

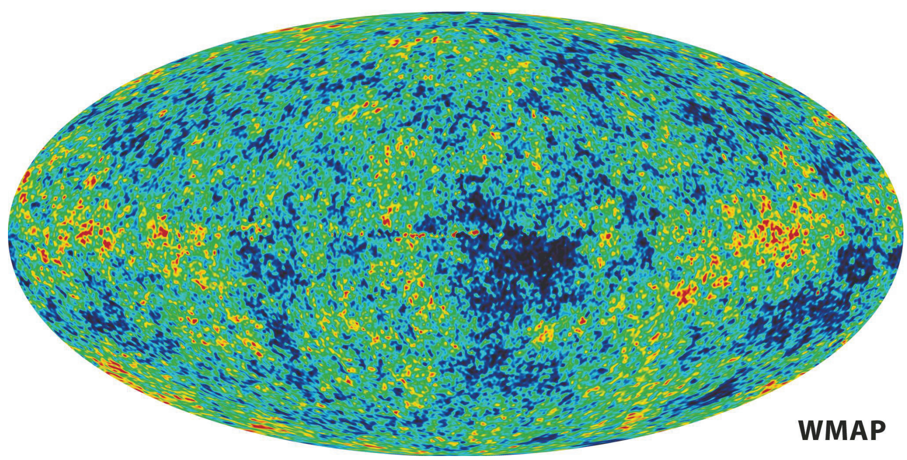
WMAP confirms that the CMB has "peaks" from the Big Bang shockwaves. The shockwaves were first observed in 1999 and 2000 with Earth-based instruments. From the first observations, astronomers made the conclusion that the geometry of the universe was flat. What that means is that in space, on a very large scale, lines that are parallel from one another, or evenly spaced from each other, would stay parallel.

WMAP has measured the peaks from the Big Bang's shockwaves. This allows astronomers to figure out how much normal matter (like atoms) and dark matter are in the universe. Taking this new information and combining it with earlier conclusions that the universe is flat, it shows astronomers how much total matter and energy the universe must have. WMAP shows that normal matter is 4% of the universe and dark matter is 23% of the universe. That means dark energy makes up 73%. These calculations fit into the amount of gravity-repelling dark energy first discovered in 1998.

For the first time, WMAP discovered the polarization of light everywhere in the CMB. This is important because it helps scientists understand what happened in the first split second after the Big Bang. Just after the Big Bang, the universe puffed up like a lump of bread dough. Astronomers call that moment "inflation," and it caused tiny changes in the original Big Bang. These variations, or differences, formed the different temperatures seen in the CMB. The tiny variations are thought to be the beginnings of today's gigantic clusters of galaxies which are strung together throughout the universe.

Researchers are now comparing and adding WMAP data with other cosmic measurements in order to have a better understanding of the universe's past, present, and future.♦





A comparison of the older COBE (top picture) and WMAP (bottom picture) results. The WMAP, or Wilkinson Microwave Anistotropy Probe, was launched in June 2001 and has made a map of temperature changes of the CMB across the sky. As you can see, WMAP is more sensitive to small temperature changes than the older COBE. Astronomers can use these fluctuations to determine different properties of the universe. (Credit: COBE and WMAP Science Teams)

Journey to Cosmos' Dark Heart

Scientists are working to understand the darkest mystery in the universe: dark energy.

NASA and the US Department of Energy are working together on a Joint Dark Energy Mission (JDEM). The mission could launch as early as 2013.

JDEM has a goal of double-checking and improving distance measurements to Type Ia supernovae. The new information should give important clues about how fast the universe has expanded throughout the history of the universe.

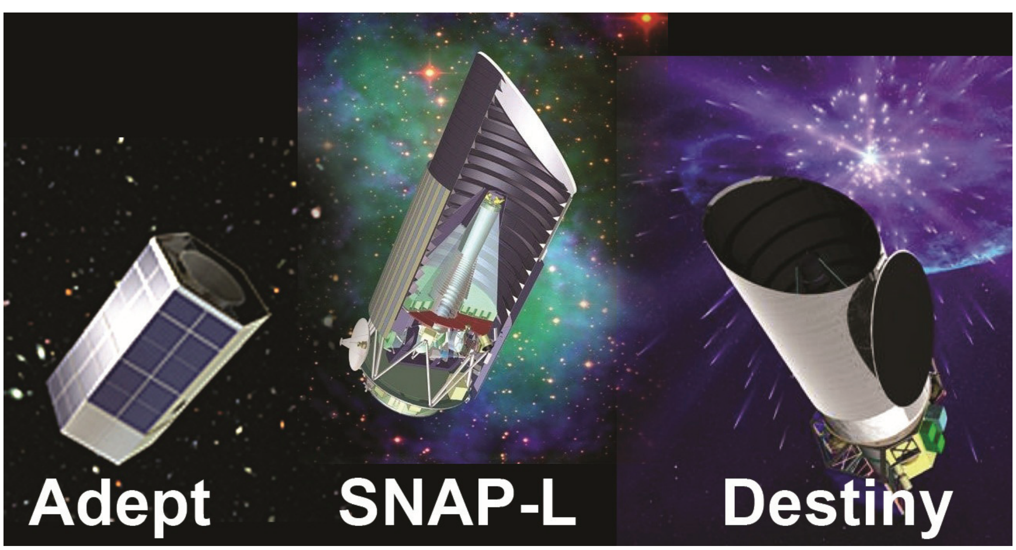
Type Ia supernovae are the "standard candles" used to determine the distances to other astronomical objects, such as far-off galaxies. By studying a large number of these "standard candles" in both near and far galaxies, astronomers are hoping they will find out how quickly the galaxies are moving away from us.

One of three observatories would be placed in space by the Joint Dark Energy Mission in order to study supernova in different ways. The three proposed studies are called the Supernova Acceleration Project (SNAP), the Advanced Dark Energy Physics Telescope (ADEPT), and the Dark Energy Space Telescope (Destiny).

SNAP would use an optical and infrared telescope with light detectors. The light detectors in this telescope are similar to what is used in digital cameras, charge-coupled devices (CCDs). SNAP's telescope would have one billion pixels, which is a thousand times stronger than any handheld camera. SNAP would detect about 2,000 Type Ia supernovae every year from a variety of distances from Earth. That would be over 200 times more supernovae than astronomers currently detect each year.

ADEPT, the second possible mission, would use a near-infrared telescope to locate 100 million galaxies and 1,000 Type Ia supernovae. The galaxies and supernovae astronomers find would be compared to the small temperature differences in the cosmic microwave background (CMB). The galaxies should show scientists how the earliest galaxies match up with the earliest clumps of matter that can be measured in the CMB. It could also show how dark energy has changed the layout of the matter since then.

The final proposed mission, Destiny, would also have a near-infrared telescope. This telescope would detect 3,000 Type Ia supernovae over two years. It would also spend one year carefully studying a large area of the sky. By studying a large section of the sky, Destiny would gather new data about the changes in the distribution or layout of matter in the universe since the Big Bang. These two parts of Destiny's mission, detecting supernovae and studying the matter in the universe, would be ten times more sensitive than similar Earth-based instruments.♦



Artist conceptions of the 3 JDEM missions.(Credit: Johns Hopkins, Lawrence Berkeley Lab, NASA/DOE)